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SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

14. ASHDOD

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This handbook for the port of Ashdod, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions made to development of port evaluations for Ashdod and Haifa by the Coastal and Marine Engineering Research Institute, Technion City, Haifa, Israel. The published evaluations make extensive use of the Institute's studies of these ports as sources of information and operational guidance.

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

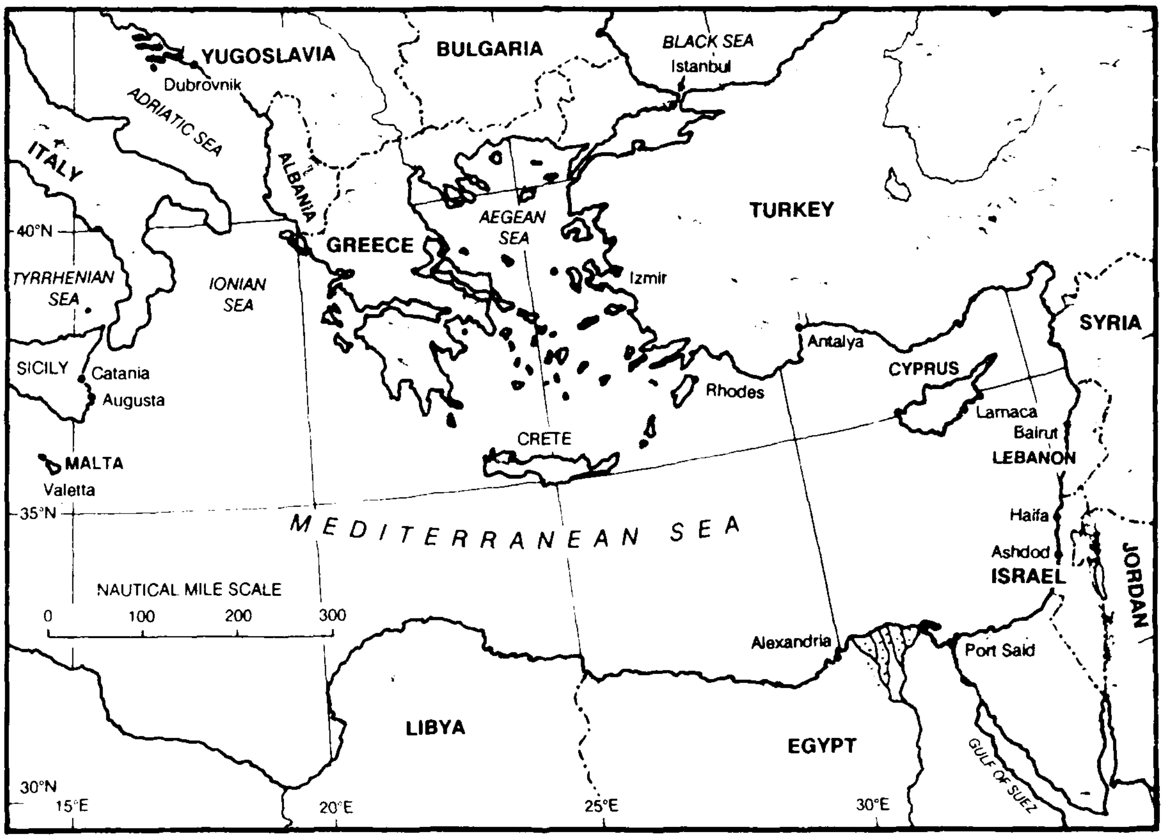
Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested precautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

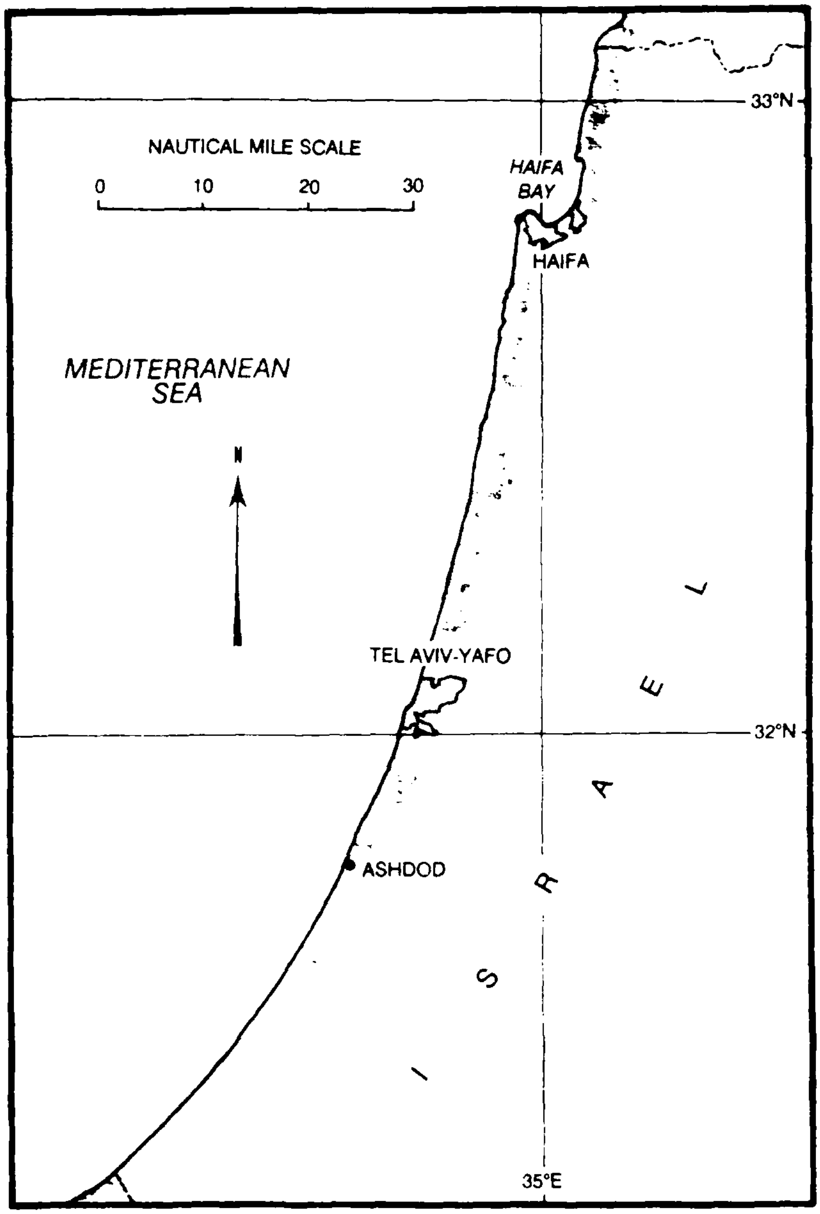
2. CAPTAIN'S SUMMARY

The Port of Ashdod is located on the coast of central Israel, near 31°49'N, 34°39'E (Figure 2-1).



2-1. Eastern Mediterranean Sea.

Ashdod, approximately 20 n mi south of Tel Aviv-Yafo, is a man made harbor on a nearly parallel coastline (Figure 2-2). The harbor is enclosed by breakwaters, but there is no natural protection from wind and waves in the surrounding coastal or offshore areas. Haifa Bay, approximately 65 n mi to the north provides the nearest protected anchorage area.



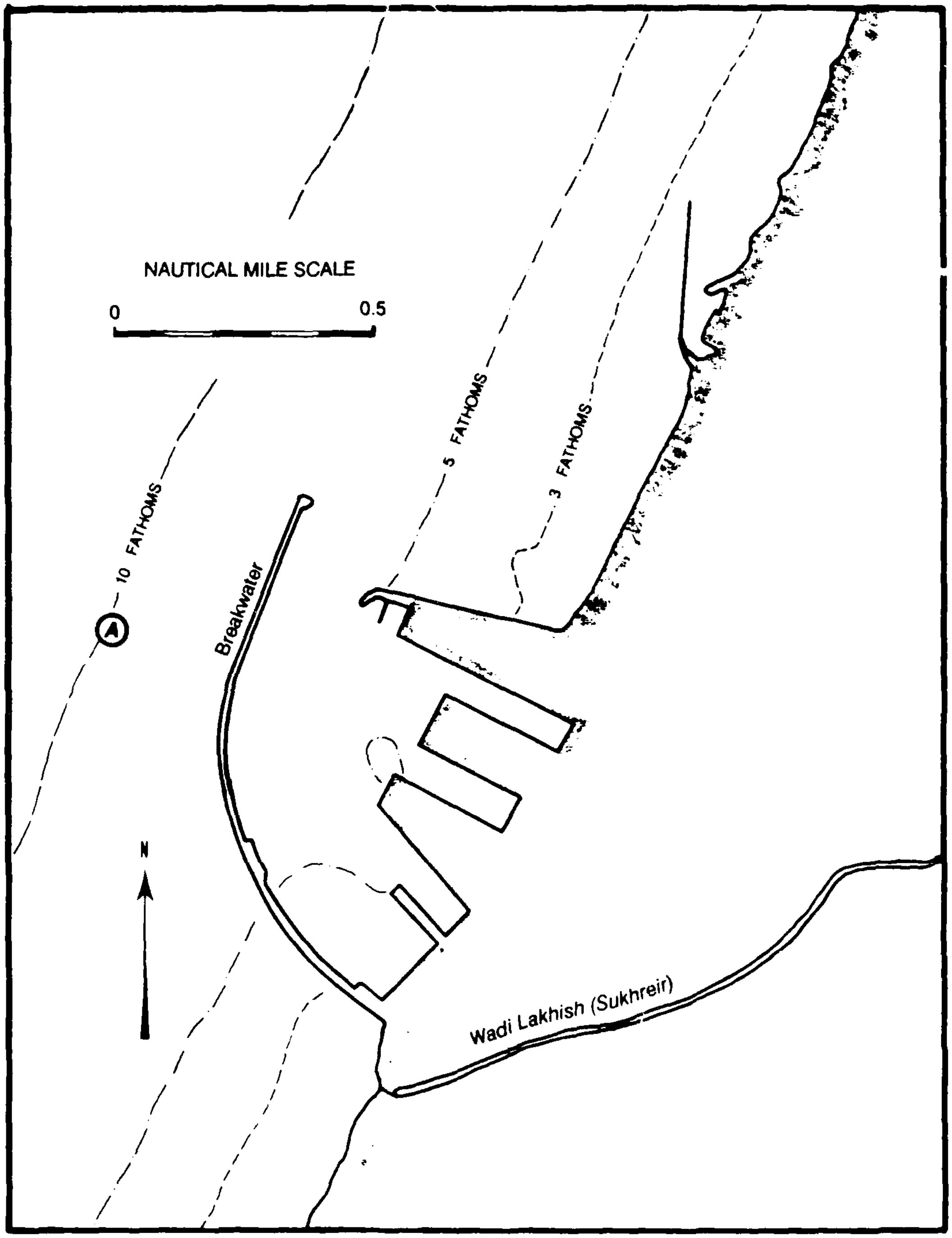
2-2. Coast of Israel.

Ashdod harbor is protected by a 7,260 ft (2200 m) long breakwater which extends seaward at the southern extreme of the harbor and then northward. The entrance, about 900 ft (270 m) wide, is located inside the northern end of this main breakwater (Figure 2-3). A second breakwater about 2,970 ft (900 m) long, defining the northern limit of the harbor, extends offshore toward the harbor entrance. The harbor accommodates vessels below carrier size with maximum wharf side depths of 34 ft (10 m).* Under storm force winds sea going vessels such as frigates or larger are advised to sortie to the open sea or Haifa Bay for anchorage.

The anchorage area is west of the main breakwater, clear of the harbor entrance (labeled 'A' on Figure 2-3). The bottom is primarily sand out to depths of about 100 ft (30 m) and a mixture of fine sand and silt from the 100 ft depth out to the coastal shelf edge. Holding properties vary in these changing bottom material zones. The anchorage area is fully exposed to winds and waves.** Deep water generated swell of 16 to 20 ft (5 to 6 m) occur during winter storms. Haifa Bay provides some protection from the high wind and wave conditions.

* Varying reports have indicated wharfside depths as much as 43 ft (13 m) in 1987. Check latest charts, Notice to Mariners, and proceed with caution.

** Historically, ships visiting Ashdod <u>do not anchor out</u>.



2-3. Port of Ashdod.

Astronomical tides in the Port of Ashdod are limited to 1 to 3 ft and tidal currents to about 0.1 kt. Near shore wave induced currents, out about 2/3 of the surf zone from the shore line, reach 3 to 4 kt during storms.

The following is a Seasonal Summary of Hazardous Weather Conditions:

WINTER (November thru February)

* Winter storms bring strong winds, accompanied by swell.
* Bora occasionally extends to the coast with force 8 to 9 westerly winds.
* Southerly Scirocco wind (warm in winter) brings poor visibility due to dust.
* Sixty percent of all strong winds occur in Dec-Feb.

SPRING (March thru May)

* Lows form off African coast moving toward Israel.
* Poorest visibilities occur in spring.

SUMMER (June thru September)

* Westerly Etesian winds reach gale force on rare occasions, accompanied by heavy swell.
* Scirocco (hot in summer) produces dust and low visibility.

AUTUMN (October)

* Short transition season. Winter starts at months end.

NOTE: For more detailed information on hazardous weather, see Summary Table 2-1, which contains specific hazardous conditions, vessel situations, and suggested precautionary/evasive action scenarios. Hazards for both inport and at anchorage are addressed.

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Table 2-1. Summary of hazardous environmental

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL SITUATI
1. Bora wind - Westerly force 8-9 (34-47 kt) following strong cold air outbreak over Aegean Sea. * Most common late winter.	Advance warning. * Cold outbreak must extend to above 850 mb level for gale force winds to reach coast of Israel.	(1) Anchore (2) In port (3) Small b
2. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) over the eastern Mediterranean. * Summer condition resulting in heavy swell.	Advance warning. * Steepening pressure gradient between thermal low over Turkey and high over Balkans. * Resulting strong northwesterly winds out of Aegean Sea.	(1) Anchore (2) In port (3) Small b

nvironmental conditions for the Port of Ashdod, Israel.

VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
(1) Anchored or in open sea.	(a) Vessels smaller than carriers. * Move to Haifa Bay or out of storm track, otherwise sortie to open sea. (b) Carriers. * Move out of storm track * In worst case, move to Haifa Bay
(2) In port.	(a) Carriers can not be serviced in Ashdod Port. * Time allowing other sea going vessels proceed to Haifa Bay, otherwise, leave Port for anchorage in open sea or if unable to leave, increase mooring lines.
(3) Small boats.	(a) Anchorage area fully exposed to open sea conditions. * Boating may be restricted/cancelled until conditions subside. * If in port remain there and add mooring lines.
(1) Anchored or in open sea.	(a) Long period (9-12 sec) west to northwest swell. * Extreme heights of 15 to 18 ft, 8 to 12 ft more typical. * Average duration about 2 days in early (May-June) and late (September-October) summer and 4 days in July and August. * Typically at least one 5 day period per year and one 10 day period about once every six years in July-August. * Move to Haifa Bay for limited protection at anchorage.
(2) In port.	(a) Port provides protection from open sea swell. * Expect heavy swell and increased currents near entrance.
(3) Small boats.	(a) Direction of long period swell and local waves likely to differ. * Small boats and larger vessels will be responding to different wave action. * Open sea operations/tending between vessels of various lengths will be hazardous. * Move to more protected waters (Haifa Bay) or delay close operations.

Table 2-1. (c

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCA SITUATION AF
3. Migratory lows - Source region changes with season. Israeli coast experiences southerly wind (Sirocco) force 7-8 (28-40 kt) as low approaches, becoming westerly force 8-9 (34-47 kt). • Southern Aegean Sea Autumn and winter. • Cyprus Area Late autumn or early spring. • North Africa Spring desert depressions.	Advance warning. • Intensification of low crossing Italy. Tend to track eastward. • Intensification of migratory low due to cold outbreak over Turkey. Low tends to become stationary for a few days. • Develops over desert south of Atlas Mountains, normally moves northeastward just south of the North African coast especially in spring. Will normally track northeast if heat trough over Turkey is deeper than 1000 mb.	(1) Anchored or in (2) In port. (3) Small boats.
4. Sea Breeze - • Late spring. • Summer. • Early autumn.	Daily occurrence.	(1) Small boats.

le 2-1. (continued)

VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
(1) Anchored or in open sea.	(a) Anchorage area fully exposed to open sea conditions. * Waves to 18 ft (5.5 m) likely in area. * Prepare to move to Haifa Bay for anchorage or enter port. (b) Most hazardous conditions occur when migratory low intensifies and becomes stationary in the Cyprus area. * Waves over 20 ft (6 m) likely in area. * Take refuge in Haifa Bay.
(2) In port.	(a) Port provides limited protection from high winds. * Local advice for vessels less than 70 m is to remain in port and add mooring lines. * For vessels greater than 70 m, leave port for open sea or anchorage in Haifa Bay.
Small boats.	(a) Wave conditions beyond small boat limits. * Enter or remain in port and add mooring lines.
Small boats.	(a) Sea breeze starts about 1000 LST, reaches maximum by 1300-1400, and dies off rapidly after 1600, calm by 1830. In September lasts until midnight but weak. * Sea breeze effects generally limited to low chop. * Local wind waves generated by sea breeze will be out of phase with swell, vessels of different lengths will respond to different wave lengths.

Shallow water wave conditions have been computed for the anchorage area indicated on Figure 2-3. The anchorage area is located about 300 yd west of the main breakwater near the 20 m depth contour. Conditions should be representative of any location of this depth in the vicinity of the port due to uniform coast line and depth contours.

Table 2-2 provides the height ratio and direction of shallow water waves to be expected at the point when the deep water wave conditions are known. The Ashdod anchorage conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height by the ratio of shallow to deep height.

Example: Use of Table 2-2 for Ashdod Point A.
Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition: 8 feet, 12 seconds, from 240°. The expected wave condition at Ashdod Point A, as determined from Table 2-2: 5 feet, 12 seconds, from 265°

NOTE: Wave periods are a conservative property and remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of the point).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

ASHDOD POINT A (500 yd west of main breakwater) 66 ft depth

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
240°	245°	250°	260°	265°	270°	270°
	.8	.8	.6	.6	.7	.6
270°	270°	270°	280°	280°	280°	290°
	1.0	1.0	.7	.7	.7	.7
300°	300°	300°	300°	300°	300°	300°
	1.0	.9	.6	.6	.6	.6
330°	325°	325°	320°	320°	315°	315°
	.8	.9	.7	.5	.6	.6

Determination of local wind generated wave data is not applicable to this area of straight coastline. Winds from offshore directions have virtually no fetch length and winds waves from seaward are generally not fetch limited.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-3. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 2-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 (1 m) ft and greater than 6.6 ft (2 m) by climatological season.

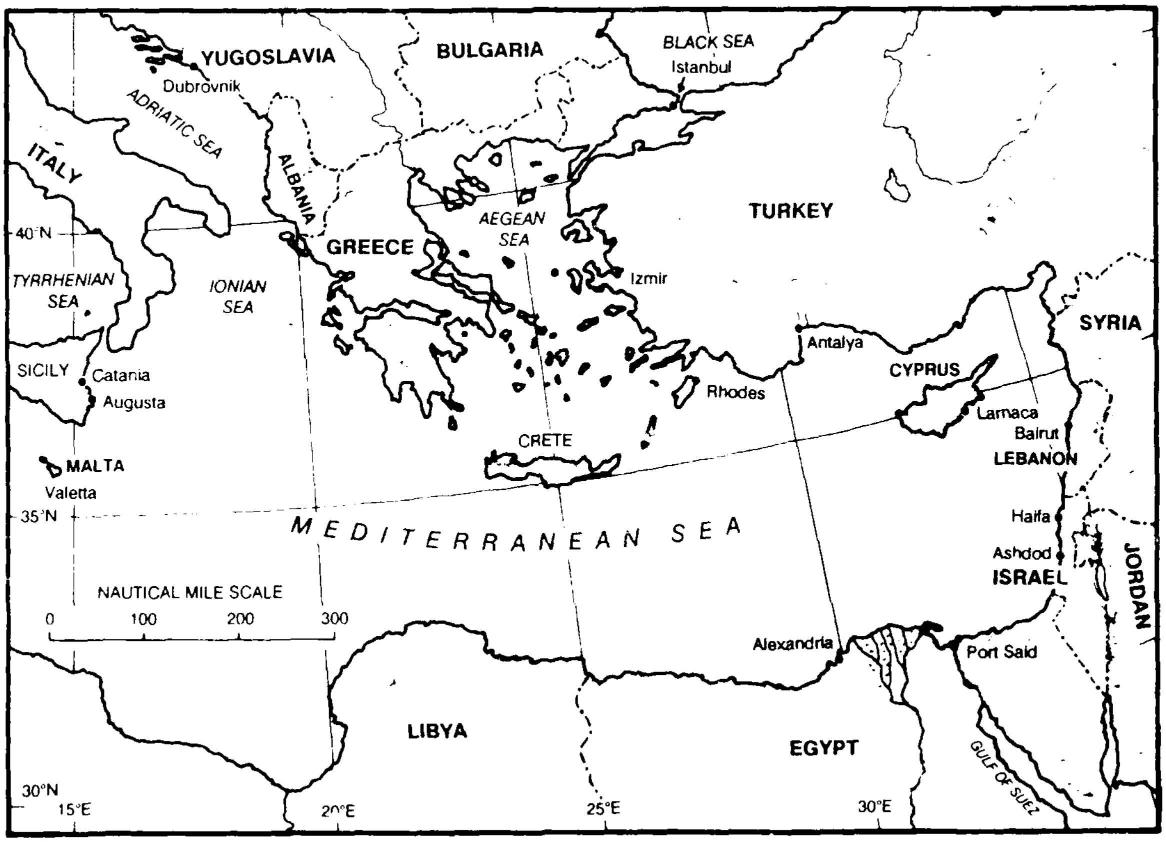
ASHDOD POINT A:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	39	32	43	19
Average Duration (hr)	18	19	21	17
Period Max Energy (sec)	9	8	8-9	9
>6.6 ft (2 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	10	7	6	1
Average Duration (hr)	13	17	16	21
Period Max Energy (sec)	9	9	9	9

3. GENERAL INFORMATION

This section expands on the material in the Captain's Summary. Some Figures and Tables are repeated. Table 3-4 provides a summary of hazards and actions by season.

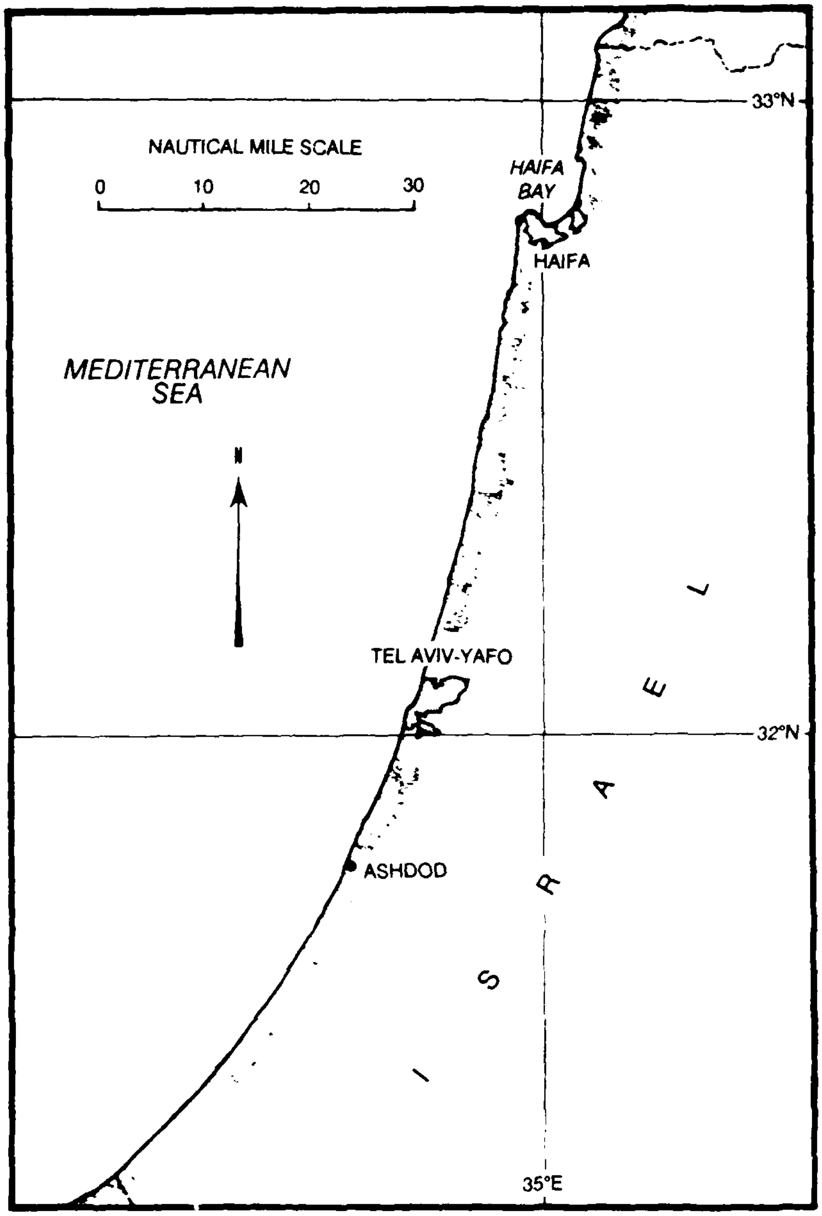
3.1 Geographic Location

The Port of Ashdod is located on the coast of central Israel, near 31°49'N, 34°39'E (Figure 3-1).



3-1. Eastern Mediterranean Sea.

Ashdod, approximately 20 n mi south of Tel Aviv-Yafo, is a man made harbor on a nearly parallel coastline (Figure 3-2). The harbor is enclosed by breakwaters, but there is no natural protection from wind and waves in the surrounding coastal or offshore areas. Haifa Bay, approximately 65 n mi to the north provides the nearest protected anchorage area.



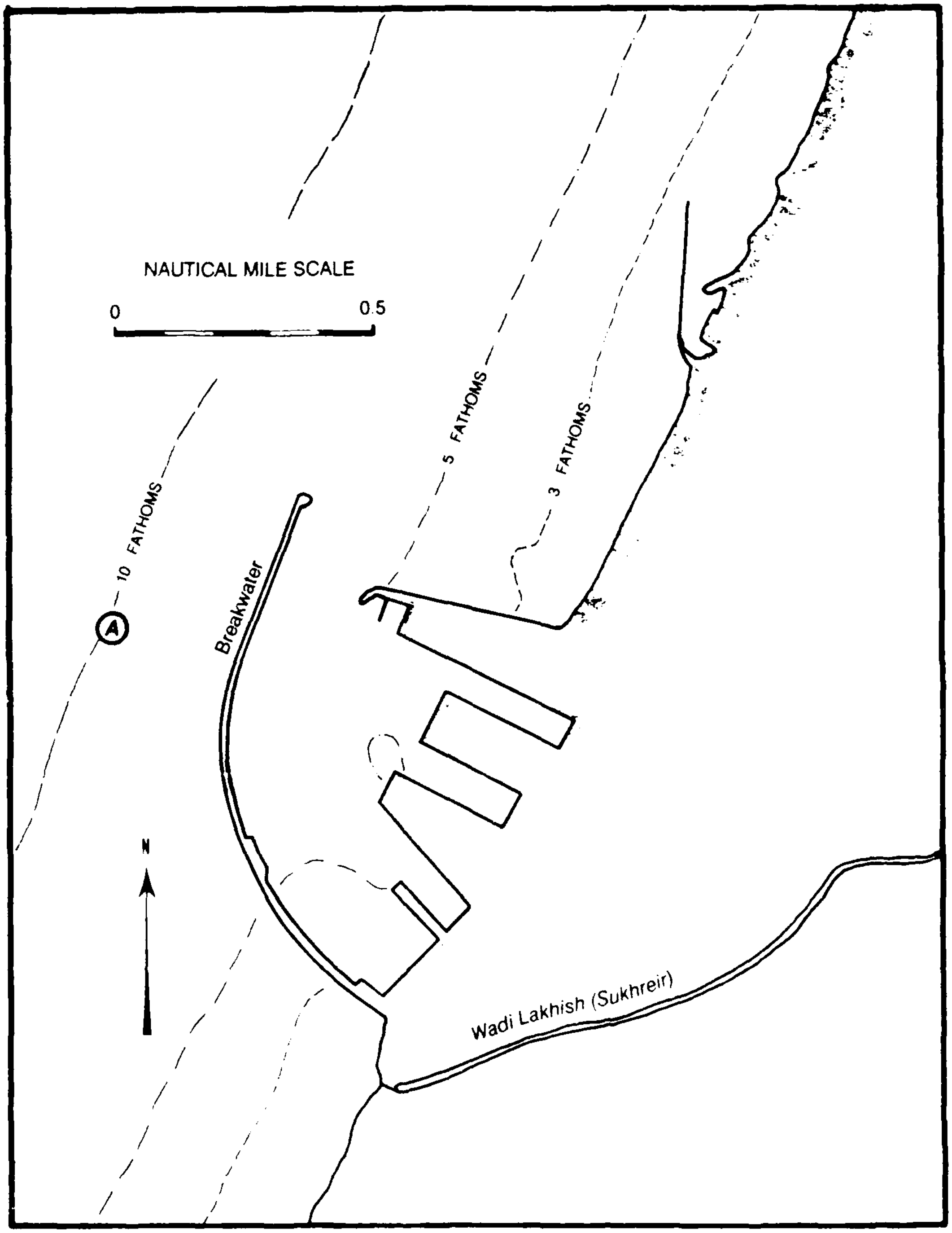
3-2. Coast of Israel.

Ashdod harbor is protected by a 7,260 ft (2200 m) long breakwater which extends seaward at the southern extreme of the harbor and then northward. The entrance, about 900 ft (270 m) wide, is located inside the northern end of this main breakwater (Figure 3-3). A second breakwater about 2,970 ft (900 m) long, defining the northern limit of the harbor, extends offshore toward the harbor entrance. The harbor accommodates vessels below carrier size with maximum wharf side depths of 34 ft (10 m).* Under storm force winds sea going vessels such as frigates or larger are advised to sortie to the open sea or Haifa Bay for anchorage.

The anchorage area is west of the main breakwater, clear of the harbor entrance (labeled 'A' on Figure 3-3). The bottom is primarily sand out to depths of about 100 ft (30 m) and a mixture of fine sand and silt from the 100 ft depth out to the coastal shelf edge. Holding properties vary in these changing bottom material zones. The anchorage area is fully exposed to winds and waves.** Deep water generated swell of 16 to 20 ft (5 to 6 m) occur during winter storms. Haifa Bay provides some protection from the high wind and wave conditions.

* Varying reports have indicated wharfside depths as much as 43 ft (13 m) in 1987. Check latest charts, Notice to Mariners, and proceed with caution.

** Historically, ships visiting Ashdod <u>do not anchor out</u>.



3-3. Port of Ashdod.

3.2 General Climate of the Mediterranean Coast of Israel

The following material and figures, except where otherwise noted, have been taken from Coastal and Marine Engineering Research Institute (Israel, 1987).

The Mediterranean coast of Israel is characterized by the so called "Mediterranean Sea climate". This climate is induced by the geographic location of the Israeli coast relative to the world pressure systems. Its characteristic properties are imposed by the subtropic highs. These highs, located between latitudes 25 and 30 degrees move with the sun, southward in winter and northward in summer. In summer these conditions lead to uniform weather with no precipitation.

In winter the region is located between two climatic areas, namely the subtropic highs in the South and the "conditioned weather" in the North. The conditioned weather area is characterized by moving lows (storms) which, when they succeed to penetrate into the Mediterranean, precipitation and bad weather conditions occur. Therefore, the winter is characterized by changing weather.

In addition to these general patterns defining the "Mediterranean Sea climate", the region is influenced by other geographic factors, which can be divided in two categories; bodies of air/source regions and monsoons.

Since the coast of Israel is located at the eastern boundary of the Mediterranean Sea, only westerly winds are wet (warm in winter and cool in summer). For other directions the winds will bring dry air (warm in summer and cold in winter).

Furthermore, the nearby African coasts, create a region of encounter between very different bodies of air - warm and dry terrestrial air from the South (desert) and cold and wet air from the North. Hence the coastal African region will be cyclogenetic, mainly in the transition seasons (spring and autumn). In summer the presence of the subtropical low will diminish any activity in that region, while in winter the desert is not hot enough and the cyclo-generation capability is weak.

Finally, the Mediterranean coast of Israel can be under the influence of monsoons coming from either NE or SE. In both cases, the pressure systems generated improve the weather conditions in this region. These systems are the Indian monsoon in summer, the Siberian high in winter and the Sudan-Ethiopian low active during all seasons, but mainly in the transition seasons, especially autumn.

3.2.1 Summer Season

The typical atmospheric pressure at sea level in summer is presented in Figure 3-4.

3.2.2 Transition Seasons (Spring and Autumn)

The transition seasons are controlled by both the subtropical highs and by passing lows. Significant patterns during these seasons are the 'Red Sea trough' and the 'heat lows', both characterized by very hot and dry weather.

Typical development and path of heat lows is represented in Figure 3-5a and the map of atmospheric pressure at the peak of the low is represented in Figure 3-5b. A typical Red Sea trough is presented in Figure 3-6a, while in Figure 3-6b the low of the Red Sea trough has moved over the southeastern Mediterranean Sea area.

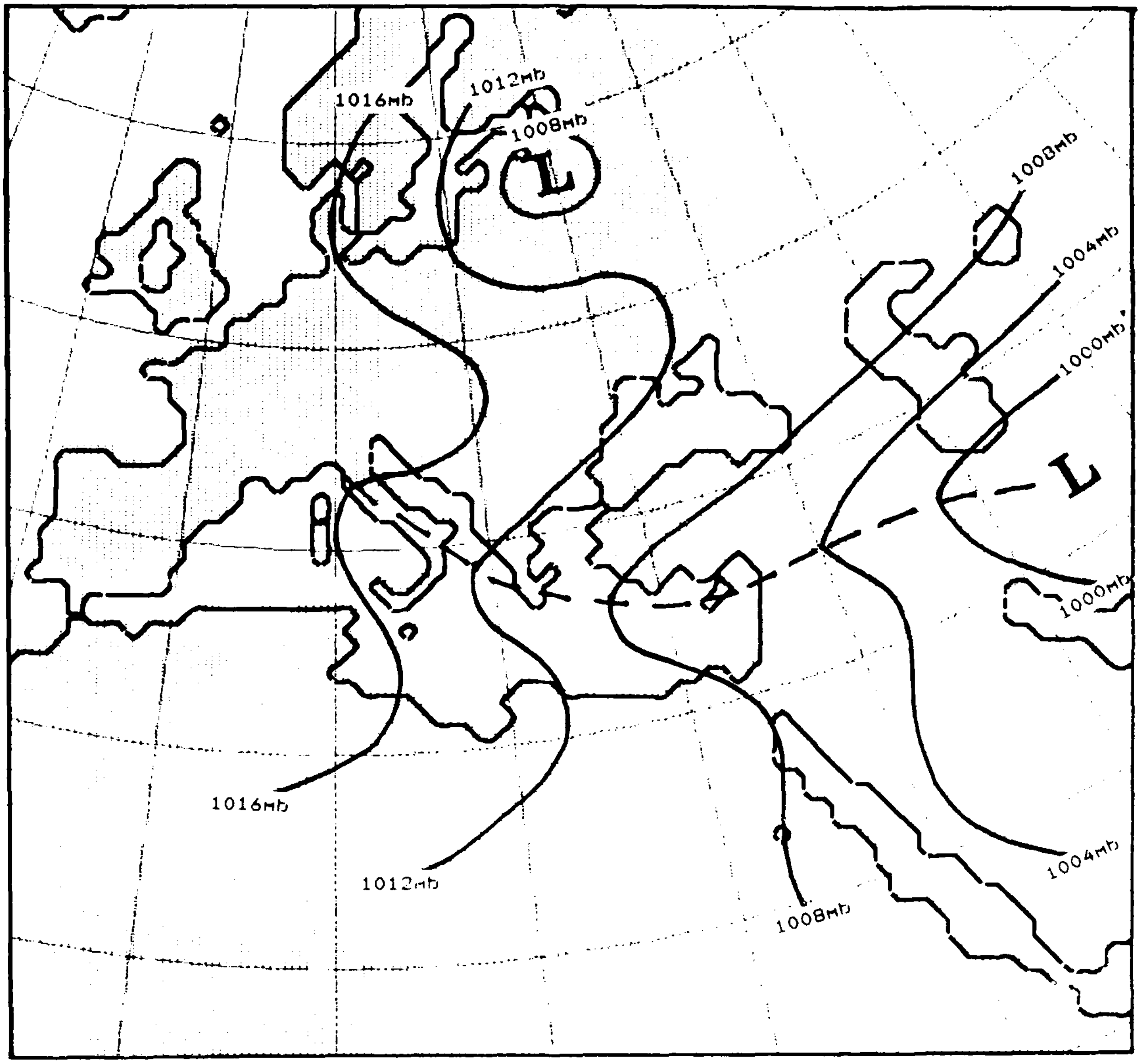


Figure 3-4. Typical synoptic surface pressure pattern for summer in the eastern Mediterranean Sea.

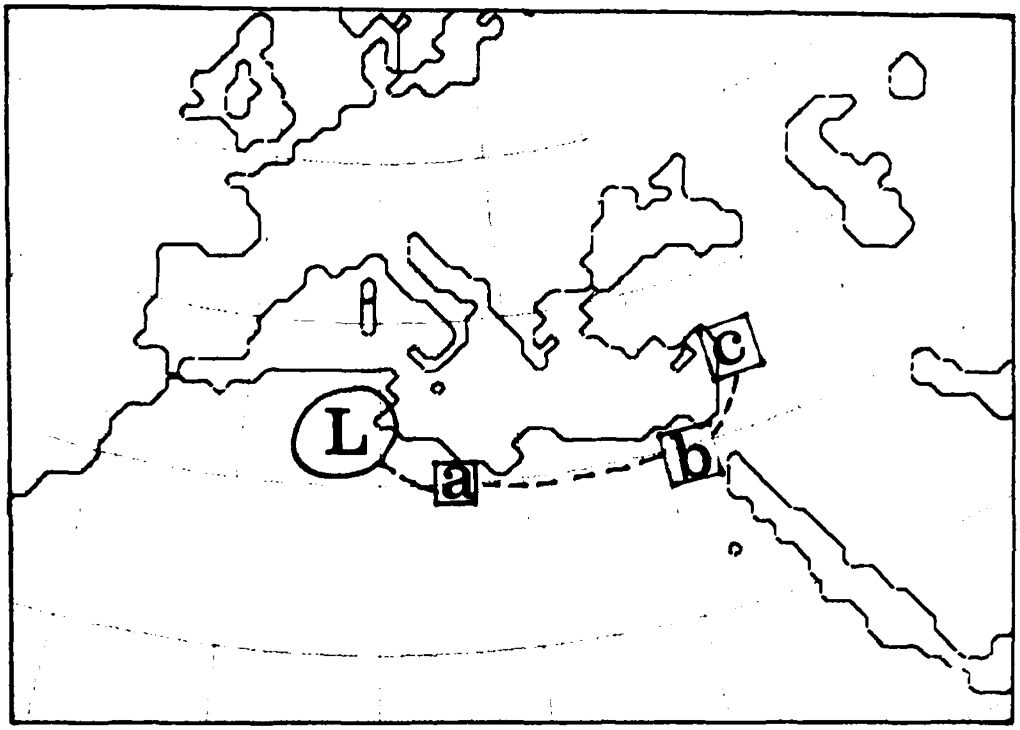


Figure 3-5a. Track of heat low during transition seasons. Position A - cloudy in eastern Mediterranean; B - peak intensity; C - hot weather subsides.

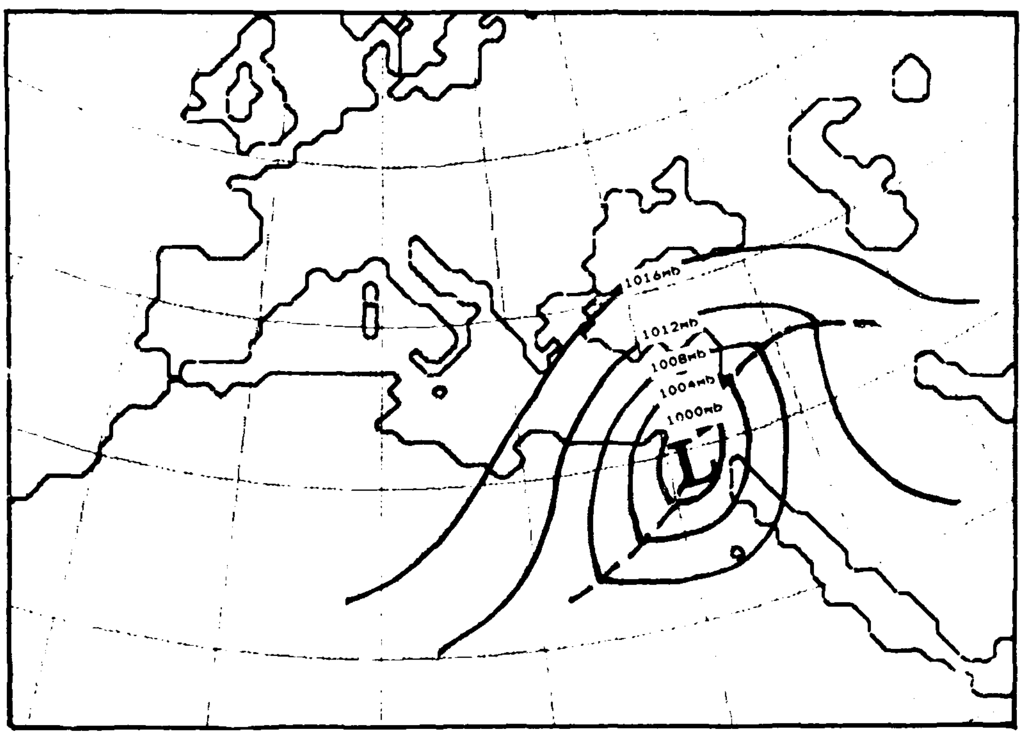


Figure 3-5b. Peak intensity of heat low during transition seasons.

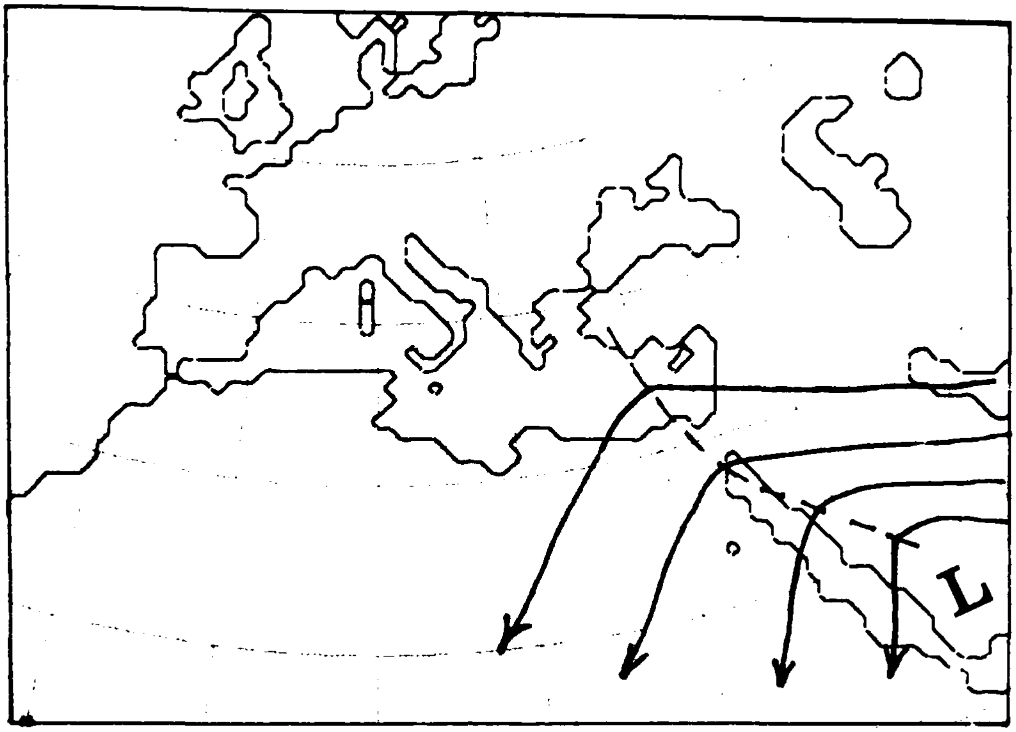


Figure 3-6a. Red Sea trough with western axis - transition seasons.

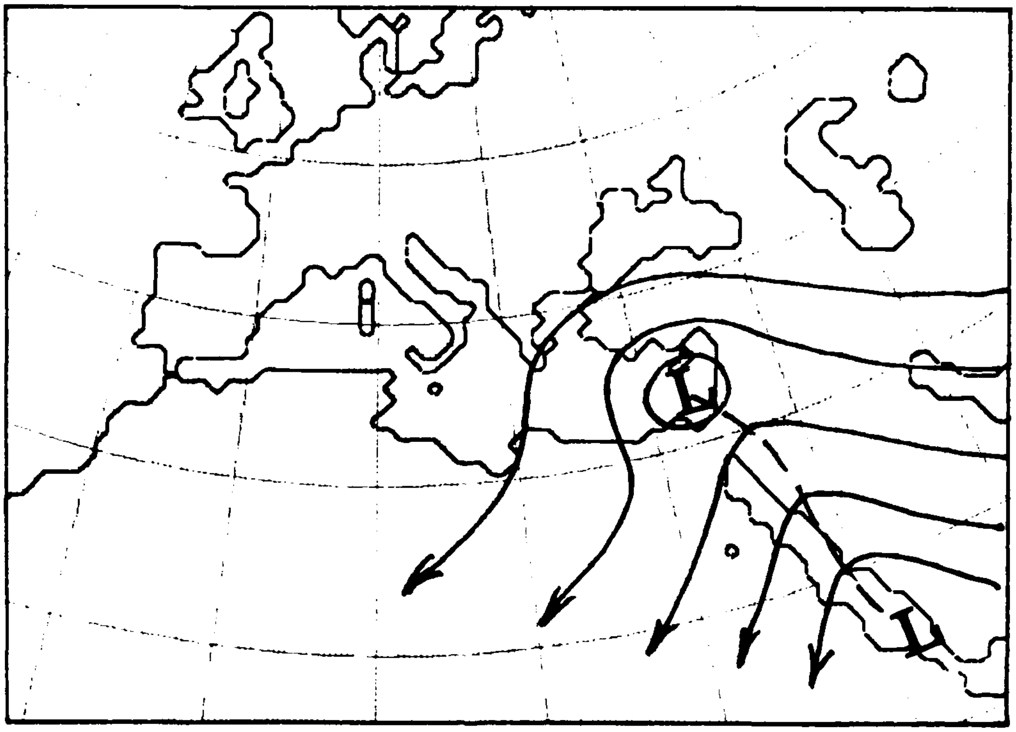


Figure 3-6b. Red Sea trough with closed low over the eastern Mediterranean - transition seasons.

3.2.3 Winter Season

Winter is characterized by changing weather, hence it is difficult to describe a representative condition. Nevertheless, certain situations lead to well defined and characteristic weather.

The most significant is the Mediterranean Sea low which originates from the strong Icelandic low, present the year around. The latter originates from the encounter between very cold polar air and the warm air raising in the area between England and Iceland due to the Gulfstream. This encounter leads to the creation of a strong source of cyclogenesis. The Mediterranean Sea low migrates in a southeasterly direction as indicated by the arrows in Figure 3-7. During its migration, the low weakens then it strengthens again near Italy.

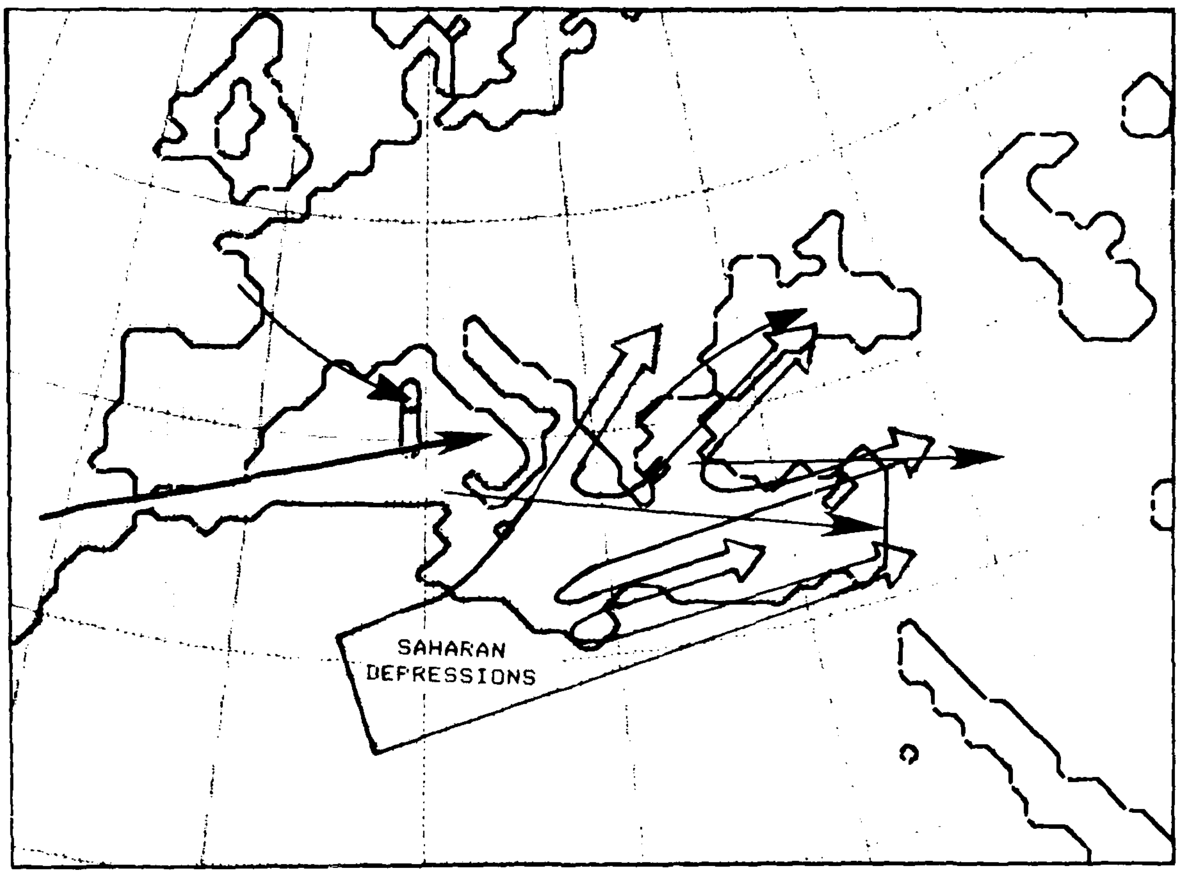


Figure 3-7. Typical storm tracks in the Mediterranean - winter season (after Reiter, 1975).

3.3 Local Wind Regimes

The following material on local wind regimes has been excerpted from Brody and Nestor (1980).

Etesian Winds

The etesian is a northerly to westerly wind that occurs during the summer over the Aegean Sea and eastern Mediterranean Sea. In the extreme eastern Mediterranean, off Israel, the etesians are westerly and normally less than gale force. The weather associated with the etesian is generally dry with good visibilities. Because of the long overwater trajectory of the air, cumulus clouds are likely. The etesian results from a combination of the following:

-- The monsoonal effect during the summer that leads to a low pressure trough over Turkey with higher pressure over the adjacent water surface.

-- Synoptic disturbances that lead to anti-cylogenesis over the Balkans. Cold air in the anticyclone following frontal passages appears to be the main cause of gale force etesians.

-- A jet-effect wind increase caused by channeling of the air between islands.

-- Mountains oriented perpendicular to the etesian which, under strong inversion conditions, block the flow and give calm seas in the lee. Strong winds are usually found only offshore from coastal valleys.

Bora

The bora is a cold, fall wind most common along the Yugoslavian coast. However, it can also occur over the Aegean Sea occasionally extending into the eastern Mediterranean. This extension of the bora from the Aegean Sea is associated with the large scale patterns over the eastern Atlantic and Europe which cause strong cold outbreaks over the Aegean Sea and Greece. The direction of the bora is usually northerly near Crete, becoming westerly off the coast of Israel. Weather associated with the bora in the eastern Mediterranean depends on the length of the overwater trajectory of the cold, initially dry air. Since the cold air has a long overwater track and picks up moisture from the relatively warm water surface, convective cloudiness and some showers can be expected.

Sirocco

The sirocco is a southeasterly to southwesterly wind over the Mediterranean originating over North Africa. Because the air's source regions are desert, the sirocco is extremely dry at its source, warm in winter, and hot in spring and summer. In the eastern Mediterranean, the sirocco originates to the south over the deserts of Libya and Egypt and over the Arabian desert to the southeast. When the source is the Arabian desert, the direction of the sirocco is often southeasterly along the Israeli coast.

Weather associated with the sirocco in the coastal areas of Israel is usually dry with visibilities occasionally poor in blowing sand and/or dust. The dust cloud layer tends to be shallow and because of the strong surface inversion produced over the water (especially in spring), anomalous radar and radio propagation are likely.

3.4 Wind Climate

Mariners should be aware that all wind records used in this study are from land stations and that a ratio of 1.6:1 has been found to be a representative ratio for estimating maximum winds over open water areas from adjacent land reports (Hsu, 1981).

The following wind climatology statistics have been taken from Coastal and Marine Engineering Research Institute (Israel, 1987).

3.4.1 Intensity Distribution

light winds (less than 10 knots)	- 81%	of the time
fresh winds (11 to 21 knots)	- 18%	of the time
strong winds (22 to 33 knots)	- 1%	of the time
winds stronger than 33 knots	- less than 1%	of the time

3.4.2 Direction Distribution

77% of the fresh winds are from the W-NW-N directions
77% of the strong winds are from the SW-W directions

3.4.3 Diurnal Distribution

81% of the strong winds are during the day, 06-09-12-15 GMT
19% of the strong winds are during the night, 18-21-00-03 GMT

3.4.4 Seasonal Distribution

94% of the strong winds are between Nov and Mar
60% of the strong winds are between Dec and Feb

3.5 Visibility

The following climatology statistics have been taken from Coastal and Marine Engineering Research Institute (Israel, 1987).

3.5.1 Annual Distribution

good visibility (>6 km)	- 92%	of the time
intermediate visibility (1-5 km)	- 4%	of the time
bad visibility (<1000 m)	- 1%	of the time
extremely bad visibility (<100 m)	- 3%	of the time

3.5.2 Diurnal Distribution

64% of the intermediate visibility conditions are at 00-03-06 GMT
76% of the bad visibility conditions are at 00-03-06 GMT
96% of the extremely bad conditions are at 21-00-03-06 GMT

3.5.3 Seasonal Distribution

60% of the bad visibility conditions occur during March to June

73% of the extremely bad visibility conditions occur during March to June

3.6 Shallow Water Wave Climate

Shallow water wave conditions have been computed for the anchorage area indicated on Figure 3-3. The anchorage area is located about 300 yd west of the main breakwater near the 20 m depth contour. Conditions should be representative of any location of this depth in the vicinity of the port due to uniform coastline and depth contours.

Table 3-1 provides the height ratio and direction of shallow water waves to be expected at the point when the deep water wave conditions are known. The Ashdod anchorage conditions are found by entering Table 3-1 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height by the ratio of shallow to deep height.

> Example: Use of Table 3-1 for Ashdod Point A.
>
> Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition:
>
> 8 feet, 12 seconds, from 240°.
>
> The expected wave condition at Ashdod Point A, as determined from Table 3-1:
>
> 5 feet, 12 seconds, from 265°

NOTE: Wave periods are a conservative property when waves move from deep to shallow water, but speed, height, and steepness change.

Table 3-1. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the point).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

ASHDOD POINT A (500 yd west of main breakwater) 66 ft depth

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
240°	245°	250°	260°	265°	270°	270°
	.8	.8	.6	.6	.7	.6
270°	270°	270°	280°	280°	280°	290°
	1.0	1.0	.7	.7	.7	.7
300°	300°	300°	300°	300°	300°	300°
	1.0	.9	.6	.6	.6	.6
330°	325°	325°	320°	320°	315°	315°
	.8	.9	.7	.5	.6	.6

Determination of local wind generated wave data is not applicable to this area of straight coastline. Winds from offshore directions have virtually no fetch length and winds waves from seaward are generally not fetch limited.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 3-2. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 3-2. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 (1 m) ft and greater than 6.6 ft (2 m) by climatological season.

ASHDOD POINT A:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	39	32	43	19
Average Duration (hr)	18	19	21	17
Period Max Energy(sec)	9	8	8-9	9
>6.6 ft (2 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	10	7	6	1
Average Duration (hr)	13	17	16	21
Period Max Energy(sec)	9	9	9	9

3.7 Tides and Water Levels

Astronomical tides in the Port of Ashdod are limited to 1 to 3 ft and tidal currents to about 0.1 kt. Near shore wave induced currents, out about 2/3 of the surf zone from the shore line, reach 3 to 4 kt during storms.

3.8 General Currents

A general current due to the water mass circulation in the Mediterranean is encountered the year around. Its activity is observed mainly in the offshore region beyond contour line of 20 m depth. Its direction is anticlockwise and parallel to the coastline and its mean velocity of about 1/4 to 1/2 knot.

3.8.1 Wave Currents

Wave induced currents occur inside the breaker zone, flowing mainly parallel to the coastline but sometimes also narrow currents flowing offshore may occur (rip currents). The maximum theoretical value of the longshore current may reach 3 to 4 knots during storms at a distance of about 2/3 of the surf zone measured from the shoreline. However, outside the surf zone the longshore current diminishes rapidly to a few centimeters per second at about 15 m water depth.

3.9 Sea Bottom Description

The sea bottom of the area opposite Ashdod port and southward is composed of sand (mean diameter about 0.25 mm) extending from shoreline to about the 30 m contour line. Beyond this depth the bottom is composed of fine sand and silt mixture to the edge of the coastal shelf.

Consequently the anchorage holding capacities differ in the two regions and depend also on the type and sizes of anchors used.

3.10 Summary of Problems, Actions, and Indicators

The following pages present Table 3-3 which discusses specific hazards and their causes and suggests evasive action.

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Table 3-3 Potential problem situation

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/E\
1. Anchored. Most common late Winter occurs Spring and Autumn	a. Bora wind - Becomes westerly, force 8-9 (37-47 kt) off coast of Israel.	a. Open sea wave and wind conditions affec anchorage. 1.) Vessels smaller than carriers advi Bay or sortie to open sea. 2.) Carriers should sortie to open sea
Summer condition	b. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) in eastern Mediterranean.	b. Long period swell (9-12 sec) from the w reaches coastal waters of Israel. Heights (2-3 m) are typical, extreme heights of 15 direction of swell and local wind waves lik 1.) Moving to Haifa Bay anchorage will protection. 2.) Be aware of varying response to wa different lengths.
All seasons	c. Migratory lows - Begins as southerly (Sirocco) force 7-8 (28-40 kt) becoming westerly force 8-9 (34-47 kt) with waves over 20 ft (6 m) during extreme conditions.	c. Open sea wave and wind conditions affect at sea will be higher than coastal station r 1.) Vessels smaller than carriers advis Bay or sortie to open sea. 2.) Carriers should sortie to open sea conditions move to Haifa Bay.

ituations at Port of Ashdod - ALL SEASONS

IONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
nditions affect unprotected carriers advised to move to Haifa ie to open sea.	a. Result of deep cold air outbreak over Aegean Sea. 1.) Strong northwesterly flow channeled east of Crete and becomes westerly over eastern Mediterranean. 2.) For Bora caused winds to reach the Israeli coast area, cold air over southern Aegean Sea must extend above 850 mb level.
ec) from the west to northwest el. Heights of 8 to 12 ft heights of 15 to 18 ft occur, wind waves likely to differ. anchorage will provide some response to waves by vessels of	b. Result of steepening pressure gradient between thermal low over Turkey and high pressure over the Balkans. 1.) The average duration is about 2 days during early (May-June) and late (September-October) summer and about 4 days during July and August. 2.) Typically at least one 5 day period each year and one 10 day period about every 6 years during July and August.
nditions affect anchorage. Winds astal station reports. carriers advised to move to Haifa ie to open sea and in extreme	c. The source region of migratory lows varies with season. 1.) Migratory mid latitude lows often intensify over the southern Aegean Sea after crossing Italy, this occurs most often during autumn and winter. 2.) During late autumn and early spring these same migratory lows at times become nearly stationary near Cyprus and intensify again when a strong cold air outbreak occurs over Turkey. 3.) All migratory lows and fronts should be closely monitored for new developments. Upper level short wave troughs and low level cold air outbreaks are features most often associated with redevelopment. 4.) Lows forming over the desert south of the Atlas Mountains of North Africa tend to track northeastward out of the Gulf of Gabes. During spring some of these North African lows track eastward and remain over land until reaching the eastern Mediterranean. These result in extensive dust layers aloft as well as heavy seas and winds off the Israeli coast. The highest winds in these cases tend to be in the northwest sector (over open sea) of the lows.

Table 3-3 (cc

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EV
2. Arriving/Departing. Most common late Winter occurs Spring and Autumn	a. Bora wind - Becomes westerly, force 8-9 (37-47 kt) off coast of Israel.	a. Open sea wave and wind conditions aff anchorage. All vessels should: 1.) Delay arrival or proceed to Haif protected anchorage/port. 2.) Depart early for open sea or Hai 3.) Reduce speed of advance if under
Summer condition	b. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) in eastern Mediterranean.	b. Long period swell (9-12 sec) from the reaches coastal waters of Israel. Height (2-3 m) are typical, extreme heights of 1 direction of swell and local wind waves l 1.) All vessels should delay arrival 2.) Depart early for open sea or Hai 3.) Direction of swell and other loc differ. Delay or take extra care in clos varying size vessels/craft.
All seasons	c. Migratory lows - Begins as southerly (Sirocco) force 7-8 (28-40 kt) becoming westerly force 8-9 (34-47 kt) with waves over 20 ft (6 m) during extreme conditions.	c. Open sea wave and wind conditions aff at sea will be higher than coastal statio 1.) Delay arrival or depart early fo Bay.

3-3 (continued)

TIO[illegible]SIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
nd conditions affect unprotected should: proceed to Haifa Bay for more open sea or Haifa Bay. advance if underway.	a. Result of deep cold air outbreak over Aegean Sea. 1.) Strong northwesterly flow channeled east of Crete and becomes westerly over eastern Mediterranean. 2.) For Bora caused winds to reach the Israeli coast area, cold air over southern Aegean Sea must extend above 850 mb level.
12 sec) from the west to northwest Israel. Heights of 8 to 12 ft me heights of 15 to 18 ft occur, cal wind waves likely to differ. ld delay arrival. open sea or Haifa Bay. ll and other local waves likely to tra care in close operations of	b. Result of steepening pressure gradient between thermal low over Turkey and high pressure over the Balkans. 1.) The average duration is about 2 days during early (May-June) and late (September-October) summer and about 4 days during July and August. 2.) Typically at least one 5 day period each year and one 10 day period about every 6 years during July and August.
d conditions affect anchorage. Winds n coastal station reports. depart early for open sea or Haifa	c. The source region of migratory lows varies with season. 1.) Migratory mid latitude lows often intensify over the southern Aegean Sea after crossing Italy, this occurs most often during autumn and winter. 2.) During late autumn and early spring these same migratory lows at times become nearly stationary near Cyprus and intensify again when a strong cold air outbreak occurs over Turkey. 3.) All migratory lows and fronts should be closely monitored for new developments. Upper level short wave troughs and low level cold air outbreaks are features most often associated with redevelopment. 4.) Lows forming over the desert south of the Atlas Mountains of North Africa tend to track northeastward out of the Gulf of Gabes. During spring some of these North African lows track eastward and remain over land until reaching the eastern Mediterranean. These result in extensive dust layers aloft as well as heavy seas and winds off the Israeli coast. The highest winds in these cases tend to be in the northwest sector (over open sea) of the lows.

Table 3-3 (c

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT PRECAUTIONARY/E
3. Small boats. Most common late Winter occurs Spring and Autumn	a. Bora wind - Becomes westerly, force 8-9 (37-47 kt) off coast of Israel.	a. Open sea wave and wind conditions af anchorage. All vessels should: 1.) Stay in port, add mooring lines 2.) If at sea proceed to nearest pr preferably Haifa.
Summer condition	b. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) in eastern Mediterranean.	b. Long period swell (9-12 sec) from th reaches coastal waters of Israel. Heigh (2-3 m) are typical, extreme heights of direction of swell and local wind waves 1.) Consider characteristics of ves period swell before departing protection 2.) Beware of breaker action near e 3.) Be alert to varying responses b length to swell and local waves when con operations.
All seasons	c. Migratory lows - Begins as southerly (Sirocco) force 7-8 (28-40 kt) becoming westerly force 8-9 (34-47 kt) with waves over 20 ft (6 m) during extreme conditions.	c. Open sea wave and wind conditions af at sea will be higher than coastal statio 1.) Open sea conditions beyond small sea proceed to nearest protected port at storm threat. 2.) If caught at sea get help and pr 3.) Stay in port and add mooring li
4. Flight operations. All seasons	a. All high wind and heavy sea conditions.	a. Follow normal heavy weather flight op
Spring and Summer	b. Reduced slant range visibility resulting from dust aloft and/or salt haze.	b. Dust and salt haze aloft cause sunlig 1.) Slant ranges are reduced signifi surface horizontal ranges. 2.) The condition is most severe wh angle sun. 3.) After dark the effect is minimal slant range visibilities will be nearly e

Table 3-3 (continued)

AUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
wind conditions affect unprotected s should: add mooring lines. ceed to nearest protected port,	a. Result of deep cold air outbreak over Aegean Sea. 1.) Strong northwesterly flow channeled east of Crete and becomes westerly over eastern Mediterranean. 2.) For Bora caused winds to reach the Israeli coast area, cold air over southern Aegean Sea must extend above 850 mb level.
(9-12 sec) from the west to northwest of Israel. Heights of 8 to 12 ft treme heights of 15 to 18 ft occur, local wind waves likely to differ. acteristics of vessel in heavy long parting protection of harbor. aker action near entrance to harbor(s). arying responses by vessels of different cal waves when conducting along side	b. Result of steepening pressure gradient between thermal low over Turkey and high pressure over the Balkans. 1.) The average duration is about 2 days during early (May-June) and late (September-October) summer and about 4 days during July and August. 2.) Typically at least one 5 day period each year and one 10 day period about every 6 years during July and August.
wind conditions affect anchorage. Winds than coastal station reports. tions beyond small boat limits. If at protected port at earliest indication of sea get help and proceed to nearest port. nd add mooring lines.	c. The source region of migratory lows varies with season. 1.) Migratory mid latitude lows often intensify over the southern Aegean Sea after crossing Italy, this occurs most often during autumn and winter. 2.) During late autumn and early spring these same migratory lows at times become nearly stationary near Cyprus and intensify again when a strong cold air outbreak occurs over Turkey. 3.) All migratory lows and fronts should be closely monitored for new developments. Upper level short wave troughs and low level cold air outbreaks are features most often associated with redevelopment. 4.) Lows forming over the desert south of the Atlas Mountains of North Africa tend to track northeastward out of the Gulf of Gabes. During spring some of these North African lows track eastward and remain over land until reaching the eastern Mediterranean. These result in extensive dust layers aloft as well as heavy seas and winds off the Israeli coast. The highest winds in these cases tend to be in the northwest sector (over open sea) of the lows.
weather flight operation procedures.	a. All prior discussions on advance indicators and supporting information applies.
aloft cause sunlight to be scattered. re reduced significantly more than es. is most severe when viewed toward a low effect is minimal. Horizontal and s will be nearly equal.	b. Reductions to visibility can be caused by either high winds or stagnate air conditions. 1.) Dust aloft is caused by winds blowing off the desert areas. The north African lows and Sirocco winds are the major cause. 2.) Salt haze is mainly a summer time phenomenon associated with stagnate air masses. The condition tends to prevail throughout the summer at various levels of severity and is wide spread over Mediterranean Sea.

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APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) / (hrs)	Sig Wave (H1/3) Period/Height (sec) / (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

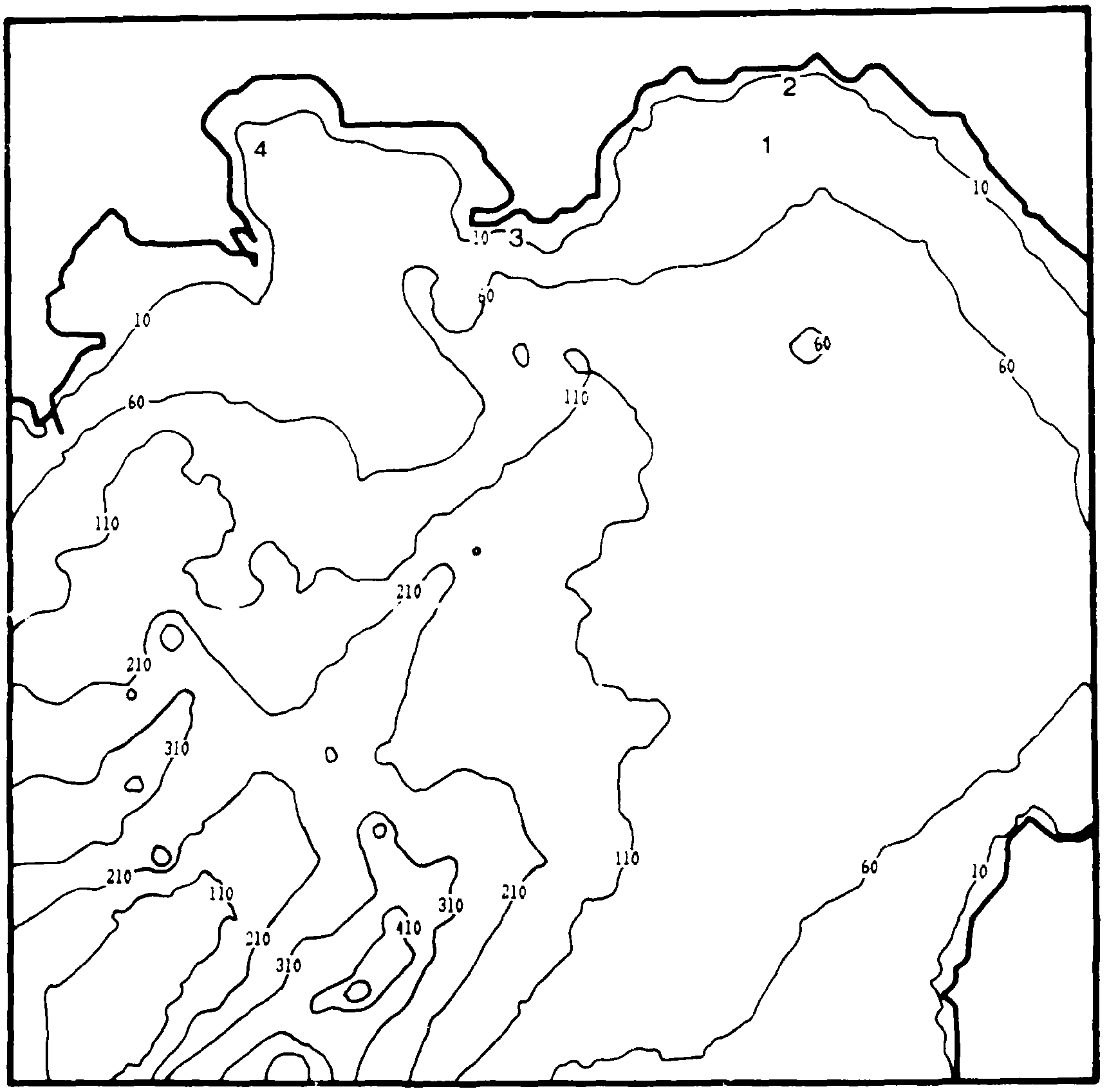

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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